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**Wang**

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(54) **DEVICES FOR COUPLING A  
LIGHT-EMITTING COMPONENT AND A  
PHOTOSENSING COMPONENT**

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See application file for complete search history.

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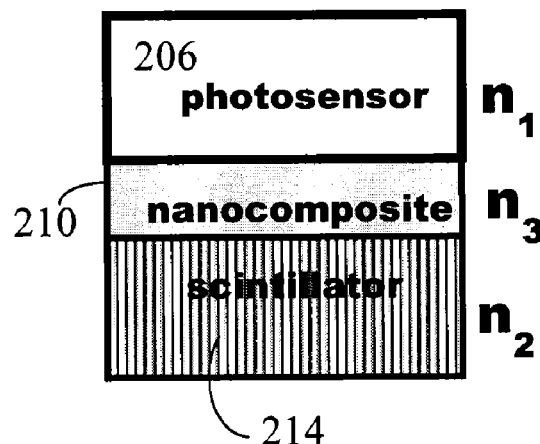
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(57) **ABSTRACT**

A radiation detector is provided including a photosensor, a scintillator, and a light guide arranged between the scintillator and the photosensor and configured to guide light from the scintillator to the photosensor, the light guide including a nano-composite that includes nanoparticles that determine a refractive index of the nano-composite. The nano-composite includes a polymer material and the nano-particles, wherein the nano-particles are uniformly distributed throughout the polymer material so that the refractive index of the nano-composite is uniform throughout the nano-composite. Alternatively, the nano-particles are distributed throughout the polymer material so that the refractive index of the nano-composite is equal to the refractive index of the photosensor at a first boundary of the nano-composite that contacts the photosensor, is equal to the refractive index of the scintillator at a second boundary of the nano-composite that contacts the scintillator, and varies uniformly throughout the nano-composite between the first and second boundaries.

**5 Claims, 2 Drawing Sheets**



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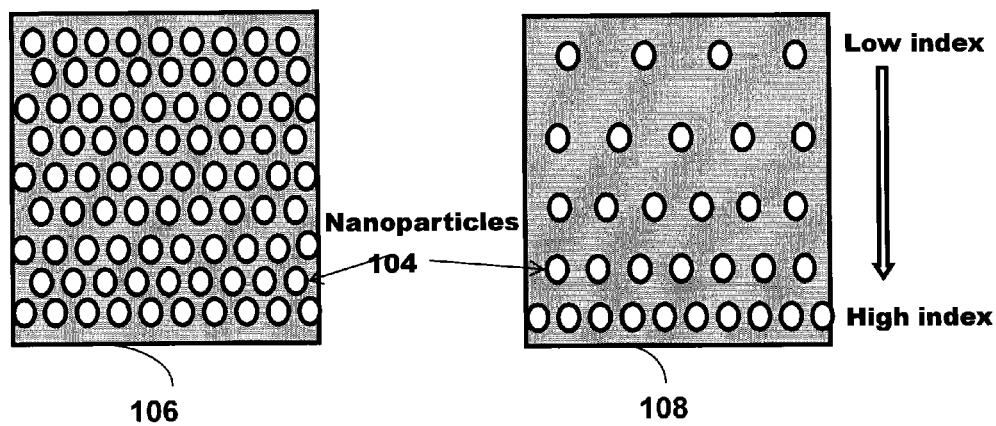


FIG. 1A

FIG. 1B

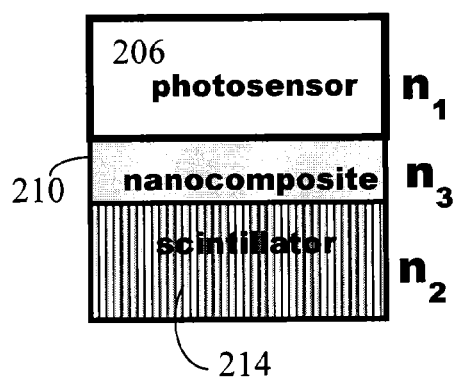


FIG. 2A

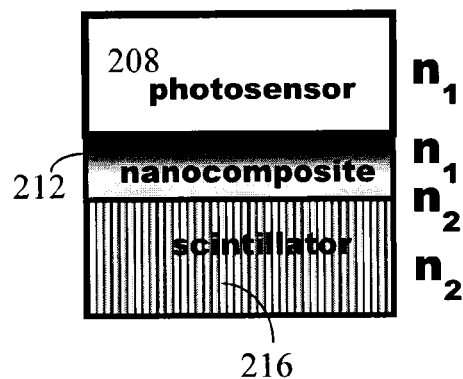


FIG. 2B

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# DEVICES FOR COUPLING A LIGHT-EMITTING COMPONENT AND A PHOTOSENSING COMPONENT

## FIELD

Embodiments disclosed herein generally relate to coupling light-emitting components and photo-sensing components using nano-composites.

## BACKGROUND

In order to get high quality CT or PET (Positron Emission Tomography) images, detectors with good properties are required. Conventionally, the refractive index of the coupling material between a light-emitting component, such as scintillator, and a photosensor, such as a photomultiplier tube (PMT), is smaller than the ideal or desired index. Also, since the material composition is uniform, the refractive index throughout the coupling region is uniform. Due to the refractive index mismatch between the light-emitting component and the photosensor, some of the scintillation light needs a relatively long time to get out of the scintillator, and some of scintillation light is trapped and lost in the scintillator. As a result, the number of photons detected by the photosensor is not as high as it should be, and photons do not reach the detector as fast as they should. This degrades the energy resolution and timing resolution of the detector. Traditionally, the light-emitting part and the photosensor are coupled with a material having a preset refractive index, which is not optimized to reduce light loss for each particular scanning application.

## BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIGS. 1A and 1B illustrate examples of coupling materials; and

FIGS. 2A and 2B illustrate radiation detectors including a photosensor, a scintillator, and the coupling materials shown in FIGS. 1A and 1B, respectively.

## DETAILED DESCRIPTION

With conventional PET scanners, it is hard to identify small lesions and to scan large patients. Thus, the embodiments disclosed herein improve energy resolution and timing resolution of radiation detectors, and thus improve, e.g., PET image quality.

According to one embodiment, there is provided a radiation detector, comprising: (1) a photosensor; (2) a scintillator; and (3) a light guide arranged between the scintillator and the photosensor and configured to guide light from the scintillator to the photosensor, the light guide comprising a nano-composite that includes nano-particles that determine a refractive index of the nano-composite.

In one embodiment, the nano-composite includes a polymer material and the nano-particles, wherein the nano-particles are uniformly distributed throughout the polymer material so that the refractive index of the nano-composite is uniform throughout the nano-composite. In particular, the refractive index of the nano-composite is substantially equal

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to the geometric mean of the refractive index of the scintillator and the refractive index of the photosensor.

In another embodiment, the nano-composite includes a polymer material and the nano-particles, wherein the nano-particles are distributed throughout the polymer material so that the refractive index of the nano-composite is equal to the refractive index of the photosensor at a first boundary of the nano-composite that contacts the photosensor, is equal to the refractive index of the scintillator at a second boundary of the nano-composite that contacts the scintillator, and varies uniformly throughout the nano-composite between the first and second boundaries.

In another embodiment, an average particle size of the nano-particles is less than 50 nm.

In another embodiment, a primer is provided to strengthen a bond between the nano-composite and the photosensor.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, FIG. 1A illustrates an example of a coupling material including a nano-composite material **106** having a uniform refractive index, while FIG. 1B illustrates a coupling material including a nano-composite material **108** having a varying (gradient) refractive index.

According to one embodiment, the nano-composite material includes a polymer matrix and a plurality of nanoparticles **104** of a predetermined material having a high refractive index, for example, larger than 2.0. The embodiments of FIGS. 1A and 1B, which have a uniform and a gradient index, respectively, are obtained by controlling the doping level of the plurality of nanoparticles.

According to one embodiment, to reduce light loss, the uniform index of the coupling material of FIG. 1A is designed to be the geometric mean of the refractive indices of the scintillator and the photosensor. Similarly, the coupling material in FIG. 1B is designed so that the refractive index at either end matches the refractive indices of the contacting photosensor and scintillator, respectively.

In each embodiment, the nano-composite can be obtained by mixing a polymer with a plurality of nanoparticles **104**. The nanoparticles **104** are made from a material with a high refractive index. In order to properly disperse the nanoparticles **104** into the matrix, the surface of the particles can be treated.

In another embodiment, the nano-composite can be made via an in-situ sol-gel process. The size of the nanoparticles **104** can be controlled by optimizing the process parameters.

During detector assembly, a gap between the scintillator and the photosensor is filled with the uncured nanocomposite coupling material. The material is later cured so that the two components, i.e., the photosensor and the scintillator, are bonded together. A primer can also be used to strengthen the bonding between the photosensor and the scintillator.

As shown in FIG. 1B, the density of the nanoparticles **104** in a particular region determines the refractive index of the nano-composite in that region. Thus, a low density of nanoparticles **104** results in a low refractive index of the nano-composite. To obtain the gradient refractive index of FIG. 1B, a doping level, the viscosity of a polymer matrix, and the curing time can be varied to obtain optimal results.

According to the present embodiments, the refractive index of the nano-composite is controlled to better match the indices of the other components. In one embodiment, the refractive index of the nano-composite is the geometric mean of the refractive indices of the scintillator and the photosensor, while in another embodiment, the nano-composite has a varying (gradient) refractive index that matches the refractive index of the components at the respective

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contact surfaces. As a result, the optical loss is reduced, light quickly exits the scintillator, and the detector performance is improved.

FIGS. 2A and 2B each illustrate a radiation detector including a photosensor and a scintillator array. FIG. 2A shows a detector including a nano-composite **210** having a uniform refractive index  $n_3$  and coupled to a photosensor **206**, having a refractive index  $n_1$ , and a scintillator **214**, having a refractive index  $n_2$ . The uniform refractive index  $n_3$  of the nano-composite **210** is, for example, as close as possible to the geometric mean of the refractive indices of the photosensor **206** and the scintillator **214**, i.e.,  $n_3 = (n_1 * n_2)^{0.5}$ . Generally,  $n_3$  can be set to be within 10% of the geometric mean value  $(n_1 * n_2)^{0.5}$ . Other combinations of  $n_1$  and  $n_2$  can be used for  $n_3$ .

FIG. 2B shows a detector coupled by a nano-composite **212** having a gradient index, wherein the index varies across the nano-composite to match the refractive index at each contact surface. Thus, in this embodiment, the nano-composite **212** couples the photosensor **208**, having a refractive index  $n_1$ , with the scintillator **216**, having a refractive index  $n_2$ , and the refractive index of the nano-composite **212** varies uniformly from a value of  $n_1$  at the surface of the photosensor to a value of  $n_2$  at the surface of the scintillator.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions, and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

The invention claimed is:

1. A radiation detector, comprising:

a photosensor;

a scintillator; and

a light guide arranged between the scintillator and the photosensor and configured to guide light from the

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scintillator to the photosensor, the light guide comprising a nano-composite that includes nano-particles that determine a refractive index of the nano-composite, wherein the refractive index of the nano-composite is substantially equal to the geometric mean of a refractive index of the scintillator and a refractive index of the photosensor.

2. The radiation detector of claim 1, wherein nano-composite includes a polymer material and the nano-particles, wherein the nano-particles are uniformly distributed throughout the polymer material so that the refractive index of the nano-composite is uniform throughout the nano-composite.

3. The radiation detector of claim 1, wherein an average particle size of the nano-particles is less than 50 nm.

4. The radiation detector of claim 1, further comprising a primer to strengthen a bond between the nano-composite and the photosensor, and a primer to strengthen a bond between the nano-composite and the scintillator.

5. A radiation detector, comprising:

a photosensor;

a scintillator; and

a light guide arranged between the scintillator and the photosensor and configured to guide light from the scintillator to the photosensor, the light guide comprising a nano-composite that includes nano-particles that determine a refractive index of the nano-composite, wherein the nano-composite includes a polymer material and the nano-particles, wherein the nano-particles are distributed throughout the polymer material so that the refractive index of the nano-composite is equal to the refractive index of the photosensor at a first boundary of the nano-composite that contacts the photosensor, is equal to the refractive index of the scintillator at a second boundary of the nano-composite that contacts the scintillator, and varies uniformly throughout the nano-composite between the first and second boundaries.

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